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Abstract

Occupational Noise Exposure, Risk Factors, and Hearing Loss among a Population of Factory Workers in the United States
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Occupational noise exposure is the most common cause of noise-induced hearing loss in adults. Hearing impairment is the result of complex interactions among various risk factors. In this cohort study, the effect of age, noise exposure duration, gender, and smoking as risk factors, on NIHL were analyzed among 401 workers in a large U.S. factory exposed to noise greater than 85 dBA TWA. All required data was obtained through company audiogram records and self-reported questionnaires. The relationship among hearing thresholds and risk factors were explored using t-test and chi-square tests. Prevalence of hearing loss among noise-exposed factory workers was 10.97% (using a hearing loss model 1 and 9.23% using model 2. The proportion of workers who smoke and have hearing loss is greater than workers who do not smoke, but is not significant. The proportion of male workers with hearing loss was significantly greater than female workers with hearing loss (13.50% and 2.22%, respectively; p=0.0026). Average high frequency hearing thresholds (4k, 6k and 8k Hz) was significantly higher among smokers compared to non-smokers (p=0.0435). Relative risk of hearing loss among non-smokers and smokers was no different for male workers, but 0.25 times the risk for female workers. In the present study among employees exposed to levels greater than 85 dBA, age, gender, noise exposure duration and smoking status all increase the likelihood of hearing loss. These data offer additional insight into the risk factors influencing development of hearing loss and can be used to assist in developing exposure guidelines and hearing conservation programs that will have a greater impact on reducing the burden of noise-induced hearing loss. However, confirming the effect of various risk factors on hearing loss in factory settings warrants further studies.

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Introduction

As the world continues to become more industrialized, noise as both an occupational and environmental hazard will have increasingly deleterious effects on populations around the globe. As of February 2013, the World Health Organization (WHO) estimated that over 15% of the world's population has some degree of hearing loss. Of that percentage approximately 5.3%, or over 360 million people, have disabling hearing loss (hearing loss greater than 40 dB in the better hearing ear).[12] Both congenital causes such as low birth weight and maternal rubella, and acquired causes, such as use of ototoxic drugs, chronic ear infection, or excessive noise can harm a person's hearing. However, occupational noise exposure is the most common cause of noise-induced hearing loss in adults.[3] The National Institute for Occupational Safety and Health (NIOSH) estimates that every day, approximately 30 million workers are exposed to hazardous noise levels and damaging noise levels while working.[4] Although countermeasures such as engineering controls and personal protective equipment have successfully reduced noise levels in many factories, noise-induced hearing loss (NIHL) has continually been listed as one of the most prevalent occupational health concerns.[5] Like many health hazards today, there are several risk factors that make the effect of noise on hearing loss more robust such as duration of noise exposure, noise intensity, age, and smoking. Smoking is a prevalent habit among those in manufacturing environments and presents concern for rates of hearing loss among individuals in that environment.[6] Understanding the dangers of occupational noise and the interplay of all of these risk factors can help form the basis of strategies to eliminate, or at least mitigate, this major impact on occupational health.

Sound and Noise

Although 'sound' and 'noise' are words that are often used interchangeably, they each possess distinct attributes. Physically, there is no difference between sound and noise.[7] Sound is a pressure change detectable by the human ear, whereas noise is a type (normally random and unwanted) of sound. Noise is present in almost every activity we do today and produces damage to the inner ear with multiple subsequent adverse health impacts. Noise is often described by its temporal pattern. Intermittent noise is interrupted with periods of quiet whereas continuous noise remains relatively constant (with occasional rises and falls) over time.[8]

Although over time some cochlear hair cells die off naturally as humans age, many more are damaged earlier due to exposure to high levels of noise.[9] Long-term exposure to noise is a process that often leads to gradual development of disease. This type of hearing loss is caused by chronic exposure to higher intensities of continuous noise levels. Most of this chronic noise-induced hearing loss occurs from occupational and/or industrial exposure. Sensorineural hearing loss, caused by damage to hair cells in the inner ear, usually affects higher frequencies first. This source of hearing loss, or occupational noise-induced hearing loss (ONIHL), can be caused from recreational activities such as shooting, but are more commonly caused by hazardous noise level exposures in the workplace. Occupations that are at a high risk for ONIHL include those in construction, agriculture, military, and manufacturing.[10]

Audiology, Measurement of Noise, and Hearing Impairment

Audiology is the study of hearing, hearing loss, balance, and related disorders involving hearing and the ear. The human ear is comprised of three parts – the outer, middle, and inner ear. Healthy hair cells within the ear structure are paramount to good hearing. As sound waves enter the outer ear, they travel to the eardrum and pass these vibrations to hair cells lining the cochlea in the inner ear. These hair cells generate nerve impulses, sending them along the auditory nerve to be interpreted in the brain as sound (Figure 1)[11].

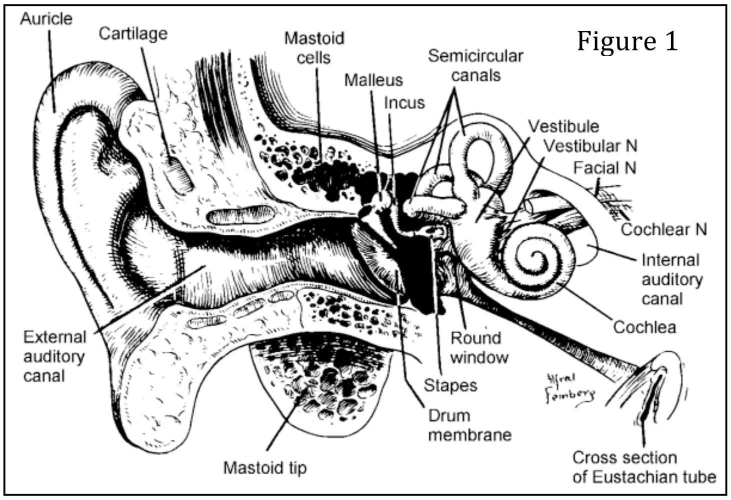


Figure 1

Exposure to noise can traumatize and thus damage these hair cells lining the cochlea in the inner ear. Hair cells can be damaged through different pathways including both apoptosis (programmed cell death – which can be triggered due to excessive noise exposure), as well as necrosis (cell death from acute cellular injury) when the damage produced from noise exceeds the hair cells' ability to repair themselves.[12,13, 14.] The outer part of the ear that detects higher sound frequencies (typically around 4,000 Hz) is affected first, and over time, the damage to hair cells begins to affect adjacent frequencies including both lower and higher sound frequencies.

Three metrics are used most often to quantify noise levels in occupational settings.[15] These include sound level, equivalent sound level, and the most important, sound pressure level. Sound pressure level measures the air vibrations that comprise sounds, or the average variation in pressure. Human ears can detect a wide range of pressure levels from 20 μPa ("audiometric zero") to 200 Pa; thus, the largest amplitude that we can hear is 10,000,000 times larger in amplitude than the smallest. However, the sensation of loudness does not have a linear relationship to sound intensity. As loudness increases in equal steps, so do the roughly equivalent increasing multiples of sound intensity.[16] A sensitivity factor is used to weight sound pressure levels at different frequencies (A-filter) and are expressed in the units, dBA. A measure for fluctuating sound levels (common in industrial settings) is equivalent sound level, which averages the A-weighted sound level over a period of time (typically 8 hours for a normal work day).[17]

OSHA set a legal limit on noise exposure in the workplace equal to a permissible exposure limit (PEL) of 85 dBA over an eight-hour day. Because sound pressure level is measured on a logarithmic scale, an increase of 3 dB in sound pressure level is equivalent to a doubling of sound intensity. Therefore, for every 3 dB increase, PEL time must be cut in half. Noise intensity, frequency, and temporality determine the extent of individual hearing loss.[18] Temporary threshold shifts (TTS) are the first signs of NIHL, however permanent threshold shifts (PTS) are plausible at prolonged exposures equal to an average sound pressure level of equal to or greater than 85 dBA over an eight-hour period.

The best way to determine hearing deterioration is to perform an audiometric test, which measures hearing ability on a decibel scale. Pure tone air conduction audiometry tests are common audiometric exams performed and required in the United States by OSHA.[19] Pure tones between 500 and 8000 Hz are presented at varying levels to determine an individual's pure tone detection thresholds (the quietest sound level detected above the audiometric zero). Data from these tests are compiled into an audiogram where hearing thresholds at various frequencies can be assessed. A change of 10 dB or greater in average change of hearing thresholds (annual audiogram threshold minus baseline audiogram threshold) at frequencies 2000, 3000, and 4000 Hz indicates a threshold shift in hearing.[20]

The audiogram helps to paint a picture of how a person hears air-conducted signals. They can be used to assess degree of individual hearing loss. Pure tone detection thresholds are plotted against frequency of pure tones conducted during the exam (Figure 5). Thresholds less than or equal to 25 dB are considered to be in the normal hearing range with mild hearing loss falling between 26 dB and 40 dB, moderate loss between 41 and 70 dB, severe hearing loss from 71 to 90 dB, and profound hearing loss at 91 dB or greater.[21]

Noise Exposure in the Manufacturing Environment

Hearing loss is the most common occupational injury and second most common self-reported occupational disease.[22] Though many sources of hazardous noise exist, workplace noise exposures are the best predictor of hearing impairment aside from age.[23] The manufacturing sector in the United States accounts for 13% of the workforce and has contributed considerably to the number of noise-induced hearing recordable illnesses. From 2004-2010, manufacturing and utilities sectors had the highest rates of occupationally related hearing loss.[24] The effects from ONIHL can have broad reaching consequences including tinnitus, physical and psychological stress, lowered productivity, interference with workplace communication, and an increase in workplace accidents.[25] Individual susceptibility to noise-induced hearing loss is highly variable. However, simultaneous exposure to hazardous noise in the presence of certain risk factors may produce a degree of hearing loss greater than what would be expected excluding such individual and environmental factors.

Cost of Hearing Loss Due To Manufacturing

Noise-induced hearing loss can impose large social and economic burdens on society. In the United States, approximately 30 million workers are exposed to hazardous levels of noise at work. Slightly more than half of these workers work in the manufacturing sector. The manufacturing industry consistently has the highest hearing loss rates among private sector. According to the Bureau of Labor Statistics, ONIHL accounts for one in nine recordable illnesses and 72% of these cases occur in manufacturing settings.[26] Not only is occupational noise exposure dangerous for workers, it is also costly for companies. Every year, an estimated $242 million is spent on worker's compensation for hearing loss disability alone in the U.S.[27]

Though NIHL is preventable, the effects are irreversible and it remains an important public health concern. In many places, excessive noise has become the most compensated occupational hazard.

Smoking and Hearing Loss

Smoking is a common habit among all social classes around the globe, especially in the working population. It is estimated that in general, over 1.3 billion individuals worldwide consume tobacco and 45.1 million adults smoke cigarettes in the United States.[28, 29, 30.] Although there is a plethora of studies supporting the adverse effects of smoking on various cancers, respiratory diseases, and cardiovascular diseases, in recent years some evidence has accumulated on the adverse effects of smoking on hearing acuity among workers.[31, 32.] Research suggests that there may me multiple mechanisms that play a role in the development of hearing loss due to exposure to smoking. The first and most common explanation is the depletion of oxygen to the cochlea from exposure to carbon monoxide and nicotine, which causes tissue damage. Smoking has also been found to cause cochlear lesions and neurotransmitter damage, further impairing hearing nerves.[33] An increase in blood viscosity and vasoconstriction (or lack of cochlear blood supply) due to smoking can cause cochlear ischemia and damage the auditory organ. Because the cochlea is characterized by high metabolic activity of the hair cells, it can be particularly vulnerable to ischemic injury.[34] Therefore, workers in loud environments who smoke are at a higher risk of developing hearing loss due to the complex interaction of these mechanisms.

Cigarette smoking has been recognized to be associated with lifestyle and socioeconomic factors that may adversely affect health of a large number of individuals exposed to noisy workplaces. Although the effects of smoking alone may not cause significant sensorineural hearing loss, the synergistic effect when combined with exposure to high levels of noise has been found to deleterious.[35, 36, 37, 38, 39] In addition, several studies have also shown a dose-response relationship between amount of smoking and NIHL.[40] Heavier smoking has a greater effect on the degree of hearing loss observed at lower hearing frequencies. The influence of smoking on noise-induced hearing loss is correlated with the quantity of cigarettes smoked daily. Risk of hearing loss among non-smokers living with a current smoker or spending hours in areas with exposure to environmental tobacco smoke has been found to be higher, although not as high as current smokers. Duration of smoking, not just intensity has been linked to an increase in hearing loss as well. Those with a higher duration of smoking accumulated a greater number of pack-years (number of packs smoked per day multiplied by number of years smoked), which has been found to have a adverse effect on hearing ability. As pack-years increase, the prevalence and risk of hearing loss also increases.[41] Both frequency and long-term smoking exacerbate noise-induced hearing loss.

Problem Statement and Objectives

NIOSH has named hearing loss as one of the top 21 priority areas for research over the next century.[42] Hearing impairment is the result of complex interactions among various risk factors. The purpose of this research study is to examine risk factors associated with hearing loss to better understand these risk factors including their severity, and interactions among them, and the resulting effects on hearing loss. The risk factors assessed in this study include age, noise exposure duration, gender, and cigarette smoking. Although work-related hearing loss from exposure to noise has long been recognized, job-related hearing loss from exposure to noise in combination with smoking has only been recognized recently. However, current studies are inconclusive regarding patterns of hearing loss in the context of smoking as a risk factor.[43, 44, 45, 46, 47.] There is need for studies that investigate the combined effects of noise and smoking habits on hearing loss so that accurate exposure limits can be established to protect workers' hearing.

Therefore, the aim of this study was to investigate the interaction between exposure to high-levels of noise and hearing loss in the context of selected risk factors, including smoking, gender, noise duration, and age.

Materials and Methods

Study Population

This study was conducted on 407 workers at a large factory in the United States aged between 20 and 71 years old and working in noisy environments. Therefore, the selected population was comprised of all female and male workers who were exposed to an 8-hour time weighted average (TWA) ≥ 85 dBA in factory work areas (n = 407). Those who did not undergo an audiometric examination during January 1, 2013 and December 31, 2013 time period were excluded (n = 6).

Of the initial sample of 407 participants, after individuals with missing audiometry records were excluded, 401 individuals were enrolled in the study.

Audiometric Testing

Examinations took place in a single-person isolated test room with a window so the qualified health technician could observe. Equipment used included an audiometer with standard or insert earphones. Every employee in the factory received a baseline audiogram within his or her first six months. All employees working in areas that equal or exceed 8-hour TWA of 85 dBA receive an annual audiometric to determine if a standard threshold shift has occurred (a change in hearing threshold of an average of 10 dB or more in either ear at 2000, 3000, or 4000 Hz). Pure tone air conduction audiometry tests were conducted for hearing thresholds at 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, and 8000Hz in both left and right ears following ISO 8253-1: 2010 methodology.[48]

Data Source

Personal protective hearing equipment has been available (and mandatory) since the plant started operations. Noise levels were determined by conducting an area survey by a certified audiometric outside contractor. Primary instruments used were Larson-Davis Models 712 or 720, which met ANSI S1.4-1983 and ANSI S1.25-1991 accuracy as type 2 integrating sound level meters. Calibrated sound level meters were set to the A scale (slow response). The A scale more closely approximates the response curve of normal human hearing.

Because history of occupational noise exposure was available for all years employed, a cumulative noise exposure metric was calculated for noise exposure assessment based on number of years worked in specified areas of the factory, as well as job function (co-op, seasonal, weekender, or full-time status). The distribution of job functions among workers exposed to 85 dBA was 1 seasonal employee (800 work hours/year), 3 co-ops (800 work hours/year), 73 weekenders (1000 work hours/year), and 324 full-time (2000 work hours/year) employees.

Pure tone air conduction audiometry test results conducted in 2013 for 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, 6000 Hz, and 8000Hz in both left and right ears were used to determine current hearing thresholds (500-6000 Hz are required frequencies and 8000 Hz is a recommended frequency to be tested[49]). Baseline audiometry results from the same sound frequencies were used to determine starting hearing thresholds among workers.

Baseline data from worker health examination queries and questionnaires were also used to collect data on health related life-style information, including smoking habits. Using self-reporting questionnaires, age, noise exposure duration, smoking status and frequency, and past medical history was examined (Appendix C). Smoking status was ascertained based on the following questions: 'Have you ever smoked?' or 'Are you a current smoker?' Non-smokers were defined as those who had never smoked in their lifetime. Since health examinations are mandatory for all employees, a participation rate of 100% was achieved.

Analysis

In this cohort study, routine annual audiometry results and employee medical histories were analyzed to assess the effect of risk factors, including smoking, age, gender, and noise duration, on hearing acuity. Noise is the only known occupational hazards affecting hearing loss at this facility.

Age was recorded in years and analyzed as a categorical variable (<40 years, 40-49 years, 50-59 years, and >60 years (only one individual was older than 60 years of age)). Participants were assigned to the smoking groups, current smoker and/or ex-smoker and non-smoker, based on questionnaire responses to this smoking habit question.

The maximum noise levels that individuals exposed to greater than 85 dBA TWA throughout areas of the plant was 108.3 dBA. Noise exposure was assessed using cumulative noise exposure durations calculated from years exposed to different noise levels and job function (seasonal, weekender, co-op, or full-time employee).

Pure tone detection thresholds (the quietest sound level detected above the audiometric zero), or average hearing thresholds, were analyzed as a continuous variable. Hearing loss was defined by two models in this study and examined between age groups, smoking status, and noise exposure. The typical pattern of NIHL seen on audiograms, known as the "noise-notch" is often used to distinguish NIHL from other etiologies such as hearing loss due to solvent exposures. Cooper and Owen found a clear decrease in hearing from 1000 Hz to 4000 Hz and several others have concluded that the first sign of NIHL (due to broad band, steady noise) was a notch at 4000 Hz.[50, 51, 52, 53, 54.] In the first model used in this study (model 1), individuals were determined to have hearing loss if the modeled hearing threshold differences between 4000 and 1000Hz in both ears was greater than 30 dBA. Model 2 was calculated in two steps based on OSHA standard calculations. Those individuals with standard thresholds shifts and who had an overall average hearing threshold level greater than 25 dB between 2k, 3k, and 4k Hz are considered to have hearing loss.[55] Hearing loss was analyzed as a dichotomous variable ('yes' / 'no').

Statistics

Hypotheses were tested primarily using t-tests and chi-square tests. Differences in population demographics such as age and cumulative noise exposure duration were compared using t-test analysis. Average hearing threshold levels were also analyzed using t-tests stratified by smoking groups and by gender. Differences in hearing loss among gender and smoking/non-smoking groups were analyzed using chi-square tests. A one-way ANOVA analysis was run to analyze average hearing thresholds among age groups. Logistic regression and additive models were also used to analyze the true effects of different risk factors on hearing loss as an outcome. Statistical analysis was performed using SAS 9.3 (SAS Institute Cary NC). A $p<0.05$ was used to define levels of significance for all tests.

Results

The mean age of all 401 workers was 47.15 years (±11.03) and mean exposure time to noise was 11.85 years (±7.84). Age and employment tenure were correlated with each other (r=0.59482; p<0.0001). The population is comprised of 77.56% of males (n=311) and 22.44% of females (n=90). Mean age for male workers was 47.15 years (±11.06 years) and 47.12 years (±11.02 years) among females (p=0.98) (Figure 2). Cumulative work years distribution was also similar among male and females, 12.07 years (±7.94 years) and 11.07 years (±7.49 years) respectively (p=0.272) (Figure 3). Differences in the average change in hearing thresholds, between male and female workers, were evident when tested at higher frequencies (Table 1).

Figure 2

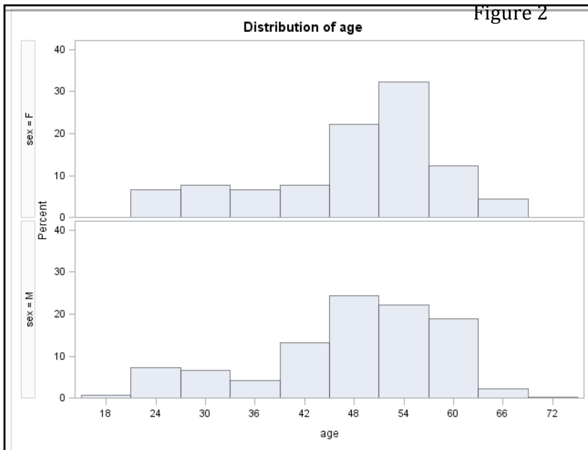
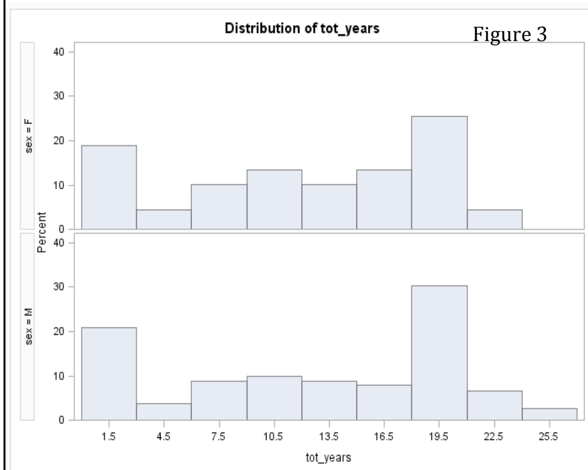


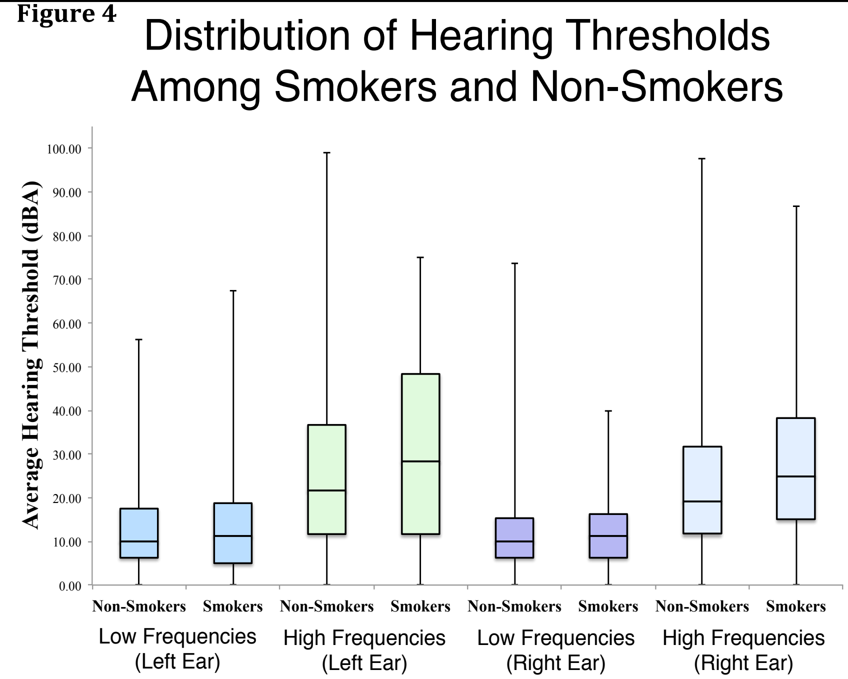
Figure 3



Among this study population, 80.8% were non-smokers and 19.2 % were current or ex-smokers (only 2 study participants claimed to be an 'ex-smoker'). Among male workers, 18.97% smoked and among all female workers, 20.0% were present or past smokers. Mean age of non-smokers and smokers was 47.7 years

(±11.3 years) and 49.04 years (±9.68 years) respectively (p=0.09). Mean noise exposure duration was 14.06 years (±7.71 years) for smokers and 11.32 years (±7.79 years) for non-smokers (p=0.006).

Figure 4



Average high frequency hearing thresholds (4000 Hz, 6000 Hz, and 8000 Hz) in the right ear was higher among smokers compared to non-smokers (28.94 and 24.18, respectively; p=0.0435) (Figure 4).

Results From Hearing Loss Model 1 (hearing threshold change of greater than 30 dB from 4k to 1k Hz)

Mean high frequency hearing thresholds (mean hearing thresholds between 4000, 6000, and 8000 Hz) among those with hearing loss was 62.29 dBA and 23.73 dBA among those without hearing loss, which is statistically significant at the 5% level (p<0.0001). Mean low frequency hearing thresholds (mean hearing thresholds between 500, 1000, 2000, and 3000 Hz) among those with hearing loss was 24.19 dBA and 11.89 dBA among those without hearing loss, which was also statistically significant ($p<0.0001$).

According to model 1 10.97% of workers (n=44) suffered from hearing loss. Among the entire population of workers, 2.22% of women (n= 2) and 13.50% of men (n=42) suffered from hearing loss. The respective proportion of hearing loss between men and women workers was statistically significant ($p=0.0026$). The percentage of workers with hearing loss among smokers and non-smokers was 11.69% and 10.80% respectively. The risk of developing hearing loss for non-smokers, when controlling for age, is estimated to be about 0.885 times the risk for smokers (95% CI 0.82, 0.95).

Results From Hearing Loss Model 2 (OSHA hearing loss calculation standard)

Mean high frequency hearing thresholds among those with hearing loss was 54.16 dBA and 25.19 dBA among those without hearing loss, which is statistically significant at the 5% level ($p<0.0001$). Mean low frequency hearing thresholds among those with hearing loss was 23.72 dBA and 12.14 dBA among those without hearing loss, which was also statistically significant ($p<0.0001$).

Standard threshold shifts (STS) in the left ear occurred in 34.98% of workers and 33% of workers in the right ear. Smoking did not have a significant effect on STS among workers ($p=0.5479$). Gender had a significant effect on STS in both left and right ears. Among left ear STS, 20% of females (n=18) and 39.87% of males (n=124) showed threshold shift in decibel levels ($p=0.0005$). Right ear distribution of STS was similar, with 18 females (20%) and 116 males (37.3% of male workers) showing a threshold shift in decibel level (p=0.0022).

According to this model, 9.23% of workers (n=37) suffered from hearing loss. Among the entire population of workers, 6.67% of women (n= 6) and 9.97% of men (n=31) suffered from hearing loss. The respective proportion of hearing loss between men and women workers was not statistically significant (p=0.3406). The percentage of workers with hearing loss among smokers and non-smokers was 10.39% and 8.95% respectively. The risk of developing hearing loss for non-smokers, when controlling for age, is estimated to be about 0.72 times the risk for smokers (95% CI 00.34, 1.5). Although the relative risk of hearing loss among smokers and non-smokers was no different among male workers, the relative risk of hearing loss among non-smokers is estimated to be 0.25 times the risk for smokers among female workers.

Discussion

In the present study among employees exposed to levels greater than 85 dBA, age, gender, noise exposure duration and smoking status all increase the likelihood of hearing loss. These findings demonstrate that hearing sensitivity also declines with progression of age and cumulative work years.

According to the results, average high and low frequency-hearing thresholds are all higher among smokers than non-smokers, but the difference is not significant. Mean age, proportion of hearing loss, and noise exposure duration among smokers was also higher than non-smokers, but noise exposure duration was the only significant difference.

The results suggest that smoking alone does not cause deterioration in hearing. But smoking in combination with gender, age, and noise exposure duration influences the hazardous effect of noise on hearing.

This study presents findings that smoking is a risk factor for decreased hearing acuteness at high frequency thresholds. No association between smoking and low frequency hearing thresholds was seen. Although the results show that smoking without the presence of other risk factors did not increase the risk for hearing loss (table 5), smoking in combination with age, gender, and noise exposure duration impacts the harmful effect of noise on hearing. Inconsistent findings have been reported on the association between smoking and hearing loss. These findings are consistent with some studies, which were not able to show a strong relationship between smoking and NIHL.[56, 57.]

These findings demonstrate that there are gender differences in hearing thresholds and hearing loss. Research exploring gender differences in hearing loss still has many unanswered questions. However, studies have found that there is typically a "gender reversal," in that difference in hearing thresholds between men and women is more apparent at high frequencies; typically with women having better hearing thresholds than men at high frequencies and lower than men at low frequencies.[58]

This study has advantages over similar studies, including a high participation rate (98.5%) as well as use of accurate employee history based on company records.

However, there are also limitations that need to be considered. First, this study does not take into account the protective nature of personal protective equipment including earmuffs and plugs. All workers entering and/or working in areas of the plant with a TWA > 85 dBA are required to wear proper PPE and discipline is taken if workers do not comply. Although all workers exposed to noise levels greater than 85 dBA were included in the study, the effect of earplugs on actual noise levels exposed to on a regular basis was not addressed. Therefore, workers at levels at or right above 85 dBA might have been exposed to low noise levels. Second, smoking history was self-reported, which might have led to underreporting of true smoking habits.

Third, accounting for use of hearing protection and its protective effect on hearing acuteness could not be examined due to lack of data on hearing protection device (HPD) usage. However, several studies have also questioned manufacturers' data for evaluation of attenuation of HPDs. A few of these studies conclude that the noise reduction rate index provided by manufacturers overestimates the true performance of hearing protectors, including under steady state continuous noise – which is of greater concern in this study's industrial setting; this is mainly due to test environments not matching real-life "imperfect" conditions.[59, 60, 61, 62, 63.]

Fourth, due to lack of company data for all employees, other risk factors that may play a role in the development of hearing loss including drug usage, head injuries, outside solvent exposures (such as at another job), or previous noisy work environments was not considered in the present study. Outside noise exposures may be one explanation for differences seen in hearing loss among men and women in this population.[64, 65.]

Conclusion

Smoking is a very common habit among all social classes, especially workers.[66] It can be concluded from this study that smoking may play a role in accelerating NIHL. Although few statistically significant results were seen among worker hearing threshold levels and prevalence of hearing loss, it does not negate the importance of smoking in terms of decreasing hearing acuity. Gender differences were seen among the effects on hearing acuteness and hearing loss. Smoking appeared to be a much more important risk factor among women in predicting hearing loss than with men. The risk of developing hearing loss while smoking was four times the risk among female workers who do not smoke; however it is important to note the limited number of subjects. Additional studies looking into biological factors including hormonal and cardiovascular gender differences should be conducted in order to learn more about gender-based etiologies in hearing loss.

The national burden of hearing loss attributable to noise at work is significant. These data offer additional insight into the risk factors influencing development of hearing loss. In the present study, among employees exposed to levels greater than 85 dBA, noise exposure duration, gender, age, and smoking status all increase the likelihood of hearing loss. These results give further insight into the extra risk associated with common risk factors in the working population. However, further research is needed to validate this conclusion and to better understand these underlying mechanisms. Effective conservation programs are needed to reduce exposure to occupational noise and smoking in order to reduce the magnitude of workers suffering from NIHL. The results from this study can be used to assist in developing exposure guidelines and hearing conservation programs that will have a greater impact on reducing the burden of noise-induced hearing loss.

Appendix A: Tables

Table 1. Summary of demographic and hearing loss results among male and female workers.

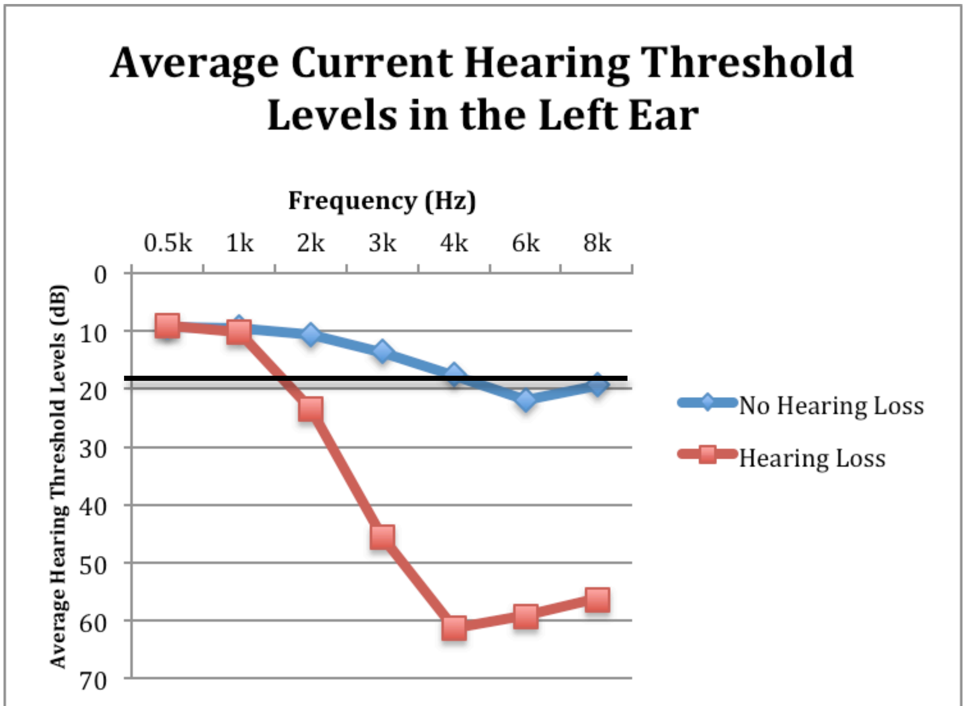
	Male n = 311		Female n = 90	
	n	Mean (std. dev.)	n	Mean (std. dev.)
Age (years)	311	47.15 (11.06)	90	47.12 (11.02)
Cumulative Noise Exposure Duration (years)	311	12.07 (7.94)	90	11.07 (7.49)
Average Hearing Thresholds (dBA)				
Low Frequency Right Ear	311	12.82 (9.35)	90	10.01 (9.05)
Low Frequency Left Ear	311	14.30 (10.38)	90	9.43 (6.90)
High Frequency Right Ear	311	27.15 (19.12)	90	16.73 (13.92)
High Frequency Left Ear	311	30.82 (20.99)	90	17.67 (13.91)
Hearing Threshold Difference 4000 Hz – 1000 Hz (dBA)				
Left Ear	311	21.59 (19.05)	90	9.83 (10.72)
Right Ear	311	18.26 (16.57)	90	8.89 (10.13)
	n	%	n	%
Smoking (yes)	59	18.97	18	20.00
Hearing Loss (yes)*	42	13.50	2	2.22

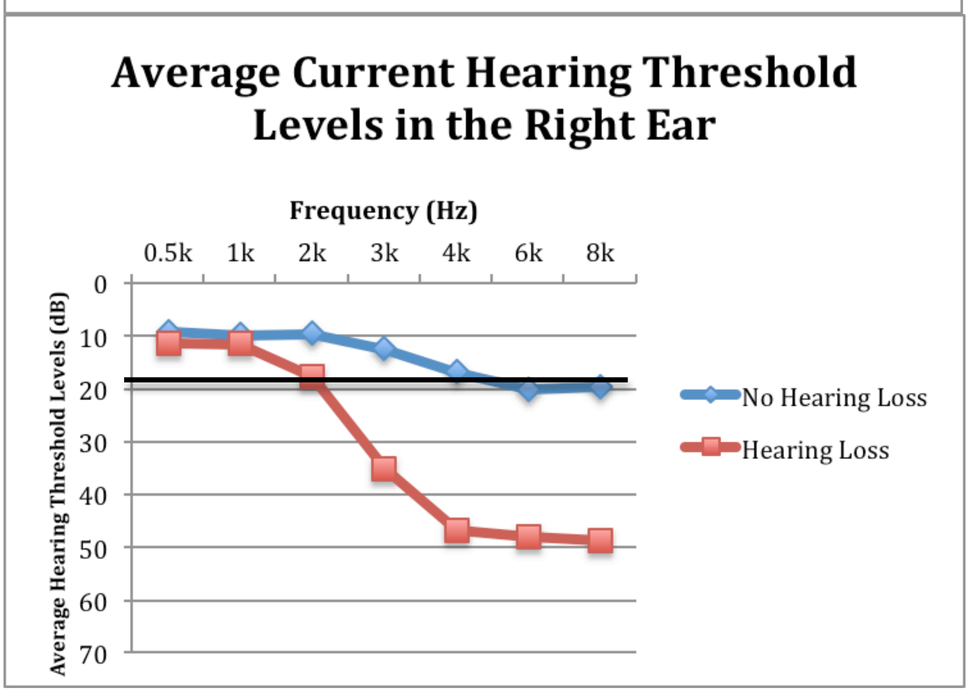
Table 2. Summary of demographic and hearing loss results among current/ex-smokers and non-smoking workers.

	Non-Smokers n = 324		Smokers n = 77	
	n	%	n	%
Age				
<40 years	77	23.77	10	12.99
40-49 years	97	29.94	23	29.87
50-59 years	120	37.04	37	48.05
60+ years	30	9.26	7	9.09
Noise Exposure Duration				
< 10 years	143	44.14	23	29.87
10+ years	181	55.86	54	70.13
Hearing Loss (according to model 1)				
Yes	35	10.80	9	11.69

Appendix B: Figures

Figure 5. Average current hearing threshold levels at tested frequencies, 0.5k, 1k, 2k, 3k, 4k, 6k, and 8k Hz, in left and right ears among those with hearing loss and those without hearing loss as defined by model 1. Zero to 20 dB (where the black line is drawn) hearing threshold level is considered to be under the "normal hearing" range.





Appendix C: Self-reported employee medical history form.

MEDICAL HISTORY FORM

COMPANY / COMPAÑIA

PLANT OR DIVISION / PLANTA o DIVISION

CITY, ST. / CIUDAD - ESTADO

LAST NAME / APELLIDO

FIRST NAME / NOMBRE — M.I. INICIAL

DATE OF BIRTH FECHA DE NACIMIENTO (MO / DAY / YEAR MES / DIA / AÑO)

GENDER / SEXO ☐ M ☐ F

A Box Must Be Checked

- ☐ PRE-EMPL / BASELINE
- ☐ ANNUAL
- ☐ RETEST
- ☐ TERMINATED / RETIRED / EXIT
- ☐ REHIRE

WORK HISTORY DATOS SOBRE SU EMPLEO

Fill in applicable blanks and circle appropriate answer.
Llene los blancos y el círculo la respuesta apropiada.

- ______ DEPARTMENT NAME / NOMBRE DE SU DEPARTAMENTO
- ______ DEPARTMENT NUMBER / NUMERO DE SU DEPARTAMENTO
- ______ NO. YEARS AT THIS COMPANY / AÑOS DEL NÚMERO EN ESTA COMPAÑÍA
- ______ JOB CLASSIFICATION or TITLE / CLASIFICACION O TITULO DE SU TRABAJO
- YES/SI NO — DO YOU REGULARLY WEAR EAR PLUGS OR MUFFS WHEN REQUIRED ON THE JOB? USA USTED TAPONES U OREJERAS EN SU TRABAJO SIEMPRE QUE SE REQUIERE?
- YES/SI NO — WEARING HEARING PROTECTION SINCE YOU GOT TO WORK TODAY? SE HA PROTEGIDO LOS OIDOS DESDE EL MOMENTO QUE ENTRO A TRABAJAR HOY?
- YES/SI NO — DO YOU WORK AT A SECOND NOISY JOB? TRABAJA EN UNA SEGUNDA OCUPACIÓN RUIDOSA?
- PLUG / MUFF / BOTH — TYPE OF HEARING PROTECTION USED? QUÉ TIPO DE PROTECCIÓN AUDITIVA UTILIZA USTED?
- YES/SI NO — PROBLEM WEARING HEARING PROTECTION? ENFRENTA ALGUNA DIFICULTAD PARA USAR TAPONES U OREJERAS?

COMMENTS (COMENTARIOS): ______

HEARING HISTORY DATOS SOBRE SU AUDICION

Check YES OR NO for each of the following questions.
Conteste cada pregunta SI o NO

YES / SI	NO		
		1. N/A	
___	___	2. SEVERE RINGING IN EARS AFTER WORK? ZUMBADO EN LOS OIDOS AL SALIR DEL TRABAJO?	
___	___	3. EARACHES, EAR INFECTIONS OR DRAINAGE FROM EARS DURING PAST YEAR? DOLOR DE OIDO, INFECCIÓN, SUPURACIÓN MAS FRECUENTE QUE UNA VEZ AL AÑO?	
___	___	4. BAD COLD OR FLU TODAY? RESFRIADO SERIO O GRIPA HOY?	
___	___	5. FREQUENT ALLERGY, ASTHMA, SINUS ATTACKS? ATAQUES FRECUENTES DE ALERGIA, ASMA O SINUSITIS?	
___	___	6. SUDDEN CHANGE OR FREQUENT CHANGES IN HEARING? PROBLEMAS AUDITIVOS?	LEFT / IZQUIERDA RIGHT / DERECHA
___	___	7. HAVE YOU EVER HAD EAR SURGERY? CIRUGIA DEL OIDO A QUALQUIER EDAD?	LEFT / IZQUIERDA RIGHT / DERECHA
___	___	8. HAVE YOU EVER HAD EAR INJURY? LESIONES DEL OIDO A CUALQUIER EDAD?	LEFT / IZQUIERDA RIGHT / DERECHA
___	___	9. DO YOU NOW WEAR A HEARING AID? ESTA USANDO AUDIFONOS ACTUALMENTE?	LEFT / IZQUIERDA RIGHT / DERECHA
___	___	10. HAVE YOU RECENTLY EXPERIENCED DIZZINESS? HA SUFRIDO DE MAREOS ÚLTIMAMENTE?	

DO YOU NOW OR DID YOU FREQUENTLY PARTICIPATE IN ANY OF THE FOLLOWING?
AL PRESENTE O PASADO, HA PARTICIPADO FREQUENTEMENTE EN LAS SIGUIENTES ACTIVIDADES?

YES / SI	NO		
___	___	SNOWMOBILES / MOTORCYCLES	SNOWMOBILE / MOTOCICLETA
___	___	MUSICIAN / LOUD MUSIC	MUSICO / MUSICA FUERTE
___	___	FARM / OPER. HEAVY MACHINERY	GRANJA / MAQUINARIA PESADA
___	___	PRIVATE FLYING / CAR RACING	AVIACIÓN PRIVADA / CORRIDA DE AUTO
___	___	HUNTING / SHOOTING	CAZA / TIRO AL BLANCO
___	___	POWERBOATING / WATER SKIING / WATERCRAFT	BOTE DE MOTOR / SKI ACUÁTICO
___	___	MILITARY SERVICE	SERVICIO MILITAR AQUI O EN SU PAIS?
___	___	POWER TOOLS / CHAINSAWS / WOODWORKING	HERRAMIENTAS ELÉCTRICAS / CARPINTERÍA

Signature / Firma: ______ Date / Fecha: ______

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